Abstract for: Analytical Fatigue Life Assessment of a Full-Scale Wind Turbine Test Bench

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In this thesis, the fatigue life of the main shaft for a large, 16 MW rated wind turbine test bench is assessed. Considering the complex loading conditions applied to the main shaft, several multiaxial damage criteria are evaluated based on their abilities to accurately predict fatigue failure and multiple multiaxial cycle counting algorithms are considered. Several critical plane approaches are compared to the IIW recommendations method for evaluating fatigue on a large set of multiaxial variable amplitude loaded welded test specimens. It is shown that the critical plane criteria can predict the fatigue life for multiaxial variable amplitude loaded specimens, with the Findley method leading to the fewest nonconservative results for the assessed critical plane criteria. A new multiaxial cycle counting algorithm is proposed that better captures shear stress ranges for complex multiaxial stress states. The new method is tested on multiaxial variable amplitude loaded welded test specimens, comparing it with three other multiaxial cycle counting algorithms with promising results. For assessing the fatigue life of the main shaft, a finite element model is developed. By testing various loading conditions applied to the main shaft, only the torque and bending loads are shown to lead to any significant fatigue damage. A measurement setup is developed for measuring strains on the main shaft during operation. The measurement system is battery-powered and can be initiated over a WiFi signal. Extensive testing is performed, and the data is analyzed and compared with the finite element model for model verification. It is shown that, for the considered strain measurements, there is less than 6% difference in the simulated and measured results. Time-varying stresses on the main shaft are evaluated using a proposed algorithm which accounts for the shaft rotation speed and time varying moments for selecting and scaling appropriate stress tensors from the finite element model. Various load conditions are considered for evaluating the fatigue life of the test bench. The worst-case load condition occurs when the main shaft rotates at its maximum rotation speed and the largest tilt moment of 25 MNm is applied. In such a case, the main shaft is predicted to fail after 15.4 years of continuous operation. Since the test bench rarely operates under such conditions, the main shaft is not expected to fail during its operational lifetime.